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ARTHROPOD SUCCESSION IN RATS EUTHANIZED WITH CARBON DIOXIDE AND SODIUM PENTOBARBITAL

Lisa A. Patrican and Rajeev Vaidyanathan[1]

Department of Entomology, Comstock Hall, Cornell University, Ithaca, New York 14853

Abstract.—Arthropod succession was observed on whole rat carcasses euthanized by CO_2 anoxia and sodium pentobarbital (SP) overdose. Adult Diptera accounted for 84% (417/494) of all arthropods collected of which 76% (319/417) were Calliphoridae. Calliphorid oviposition on SP euthanized rats was protracted throughout the first 7 d of putrefaction compared to CO_2 euthanized rats. Seventy-one percent (353/494) of adult arthropods were associated with SP euthanized rats and SP rats took twice as long to decompose. Arthropod succession and development on rat carcasses was most likely influenced by manner of death.

Key words: forensic entomology.

Cadavers exposed to air undergo a series of decompositional stages and arthropods characteristic of each stage appear in regular succession (Keh, 1985). Forensic entomologists frequently assist homicide investigations in determining the postmortem interval (PMI) or time interval between death and corpse discovery based on the diversity of arthropods present and their developmental stage relative to prevailing environmental conditions.

Manner of death can affect the rate of decomposition and arthropod succession and should be considered when using insects to determine the PMI (Smith, 1976; Catts, 1992). Insects associated with poisoned cadavers arrive and develop at different rates than those associated with mechanical deaths (Utsumi et al., 1958). Poisons can deter early invasion by ovipositing flies, larval feeding and beetle predation and inhibit organisms that enhance decomposition (Glaister and Rentoul, 1966; Lane, 1975; Nuorteva and Nuorteva, 1982; Mann et al., 1990; LeClerq and Vallant, 1992).

Substance abuse from prescription and non-prescription drugs often cause or contribute to the death of an individual. Drugs can be detected in decomposing tissues and in the maggots feeding on such tissues as reviewed by Goff and Lord (1994). The presence of drugs in decomposing tissues also influences the development and pattern of carrion feeding insects and could alter PMI estimates based on the rate of larval and puparial development. Lord (1990) described a homicide case in which a single *Phaenica serricata* (Meigen) larva recovered from the nasal region of a women with a history of cocaine abuse had undergone accelerated growth and was nearly twice the size of other *P. serricata* and *Cynomyopsis cadaverina* (R.-D.) larvae that were present. In laboratory studies, sarcophagid fly colonies developed more rapidly on tissues containing cocaine, heroin (as morphine) and metamphetamine (Goff et

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[1] Current Address: Department of Entomology, Fernald Hall, University of Massachusetts, Amherst, MA 01003.

al., 1989, 1991, 1992). Conversely, the developmental rate of *Parasarcophaga ruficornis* (F.) feeding on tissues containing the antidepressant amitriptyline was not affected however, a prolonged postfeeding period was observed (Goff et al., 1993).

The studies by Goff et al. (1989, 1991, 1992, 1993) used livers and spleens from rabbits receiving known dosages of cocaine, heroin, metamphetamine and amitriptyline as larval media and sarcophagid flies as primary necrophages. The objective of our study was to compare arthropod succession and carcass decomposition in whole rats euthanized by CO_2 anoxia and sodium pentobarbital (SP) overdose under environmental conditions common to central New York. SP, a barbituric acid derivative, is used as a veterinary anesthetic and euthanasia drug. Carbon dioxide euthanasia was selected for comparison to SP overdose because in both cases death results from anoxia (Muir III and Hubbell 1995).

MATERIALS AND METHODS

Five rats were euthanized in a CO_2 chamber and 5 rats were euthanized by intraperitoneal injection of 1.5 cc SP (Nembutal: 64.8 mg SP/cc 10% ethanol in water). Rats weighed 0.25 to 0.40 kg and were culled from a Cornell University nutrition study. Death occurred within seconds for rats receiving SP and within 5 mins for rats euthanized in the CO_2 chamber. One to 4 h after death, rats were placed in 29 $\times$ 36 $\times$ 54 cm wire cages 7 m apart in open pasture behind Schwardt Laboratory, Ithaca, NY. Rats were euthanized and placed in the field on Sept. 13, 1991 (1 CO_2 rat per cage and 1 SP rat per cage) and October 1 and 18, 1991 (2 CO_2 rats per cage and 2 SP rats per cage). Rainfall and afternoon temperature were recorded for 21, 17, and 15 days following placement of the rats in the pasture on Sept. 13, Oct. 1 and 18, respectively.

Diptera and other flying insects, fly larvae and beetles were collected daily as described by Lord and Burger (1983). Although not collected, other insects seen associated with the rat carcasses were recorded in a field notebook. No collections were made after sunset. Time required for fly larval and pupal development were also recorded. Arthropods were identified to family although some calliphorid flies, beetles and yellowjackets were identified to genus and occasionally species. Arthropod diversity and succession were correlated to the stages of decomposition and method of euthanasia. Data were analyzed by *t* test (Systat, 1992).

RESULTS

Sept. 13. Within 1 d postmortem blow fly (Calliphoridae) oviposition was extensive for both CO_2 and SP euthanized rats. For brevity, rats will be referred to as CO_2 and SP rats. Eggs were laid within the nostrils, along the genito-anal areas and along the flanks. The SP rat had eggs in its eyelids and yellowjackets (Vespidae: *Vespula maculifrons* [Buysson]) feeding at the scrotum. The left flank of the CO_2 rat was torn by yellowjackets.

Two d postmortem 0.5–0.7 cm maggots had entered the left flank of the CO_2 rat, eaten through the peritoneum and entered the viscera. The eyes were eaten and nose blood had congealed. Maggots measuring 0.3–0.5 cm on the SP rat were feeding around the face and rectum. A 1 cm larva was noted deep within the perineoscrotal cavity but was not removed. Fly larvae were not detected within the abdomen.

Yellowjackets contributed to carrion decomposition by opening the carcass to other insects.

Three d postmortem 1.1–1.4 cm second and third instars were actively feeding on the intestines, gall bladder, abdominal mesentery, face, mouth and lips of the CO_2 rat. Postfeeding third instars were beginning to leave the corpse. The SP rat was distended and first and second instars were on the nape of the neck, ears, eyes and perineum.

Four d postmortem all viscera of the CO_2 rat were eaten. The bones, hair and papery skin remained. Fly larvae had tunneled into the ground and predators such as: histerid (Histeridae) beetles, rove (Staphylinidae) beetles, sphecid (Sphecidae) wasps and assassin (Reduviidae) bugs dominated. The SP rat was bloated and second instars began feeding on the intestines, liver and kidneys. The largest fly larvae, 1.2–1.5 cm, fed within the perineoscrotal cavity.

Six d postmortem the CO_2 rat was dry. Ants (Formicidae), opilionids (Opiliones) and entomobryiid (Entomobryidae) collembolans scavenged. Much of the SP rat's esophagus and gastrointestinal tract were still intact. The next 5 d exhibited little change in the CO_2 rat whereas larval and adult calliphorids still dominated the SP rat.

The mean afternoon temperature from Sept. 13–Sept. 24 was 24°C (15–36°C). Average rainfall was 0.25 cm. Arthropods associated with the rats described above are listed in Table 1.

Oct. 1. All four CO_2 and SP rats had extensive oviposition near their perianal areas, mouths, necks and flanks within 1 d of death. Adult calliphorid flies were feeding near the rectum and face.

Within 3 d postmortem the CO_2 rats' eyes were liquefied by feeding fly larvae. First instars fed in the nose, flanks and genitourinary system of SP rats. The calliphorid flies *Lucilia* sp. and *Phaenicia* sp. continued to oviposit on the SP rat.

Within 6 d postmortem the CO_2 rats' faces were eaten and their mandibles were free, skin was blackened, fur fell off easily and larvae, having consumed the viscera, started eating the muscles. Staphylinid and histerid beetles also frequented the carcasses. In contrast, the SP rats were still intact, their flesh was pink and fly larvae were concentrated in the genito-anal area and upper thorax. Larval movement appeared somewhat languid in SP rats compared to similar instars in CO_2 rats.

Nine d postmortem the CO_2 rats' brains were eaten, their skins were tight, their thoraces deflated and postfeeding third instars were tunneling in preparation for pupation. The faces and viscera of SP rats were still intact and all fly instars were present. SP rats were mauled by vertebrates, most likely raccoons, 10 d postmortem. Over the next 6 d we observed additional desiccation, melanization and yellowing of the CO_2 rat carcasses. Seventeen d postmortem the CO_2 rats also were eaten by vertebrates.

The mean afternoon temperature from Oct. 1–Oct. 17 was 18°C (9–27°C). Average rainfall was 0.53 cm. Arthropods associated with these four rat carcasses are listed in Table 1. The number of taxa observed or collected from SP rats was significantly greater than the taxa associated with CO_2 rats ($P < 0.05$). The largest number of taxa were observed or collected from Sept. 13 SP rats 4–6 d postmortem ($P < 0.05$).

Oct. 18. The last four rats were never fully decomposed by arthropods. Four d postmortem the 2 SP rats and 1 CO_2 rat were eaten by vertebrates. The four rats

Table 1. Adult arthropod succession to rats euthanized by CO_2 anoxia and sodium pentobarbital (SP) overdose.

Days postmortem	Order[a]	September 13, 1991		October 1, 1991	
		CO_2	SP	CO_2	SP
1	Diptera	Sarcophagidae Calliphoridae Ephyridae	Calliphoridae	Calliphoridae	Calliphoridae
	Hymenoptera	Vespidae Formicidae	Vespidae		Sphecidae
	Coleoptera		Staphylinidae		
	Other	Collembola		Opiliones	Opiliones Collembola
2	Diptera	Sarcophagidae Calliphoridae	Sarcophagidae Calliphoridae	Calliphoridae Piophilidae	Calliphoridae
	Hymenoptera	Vespidae Formicidae	Vespidae		
	Coleoptera		Staphylinidae		Chrysomelidae
	Other	Opiliones Collembola		Opiliones	
3	Diptera	Sarcophagidae Calliphoridae Sphaeroceridae Muscidae	Sarcophagidae Calliphoridae Sepsidae Muscidae Anthomyiidae	Calliphoridae Sarcophagidae Muscidae	Calliphoridae Sarcophagidae Piophilidae
	Hymenoptera	Braconidae	Formicidae		Formicidae
	Coleoptera	Staphylinidae	Staphylinidae		
	Orthoptera		Gryllidae		
	Hemiptera				Reduviidae
	Other		Opiliones	Collembola	Collembola
4	Diptera		Sarcophagidae Calliphoridae Muscidae Piophilidae	Calliphoridae	Calliphoridae Muscidae

Table 1. Continued.

Days postmortem	Order[a]	September 13, 1991		October 1, 1991	
		CO_2	SP	CO_2	SP
			Sphaeroceridae		
			Chloropidae		
	Hymenoptera	Sphecidae	Vespidae		Formicidae
			Formicidae		
	Coleoptera	Staphylinidae	Histeridae	Staphylinidae	Staphylinidae
		Histeridae	Siphilidae	Histeridae	
			Staphylinidae		
	Hemiptera	Reduviidae	Reduviidae		
	Orthoptera		Gryllidae		
	Other		Acari		Collembola
5	Diptera		Sarcophagidae		Calliphoridae
			Calliphoridae		
			Muscidae		
			Phoridae		
			Sciaridae		
			Sphaeroceridae		
	Hymenoptera	Formicidae	Formicidae		Braconidae
	Coleoptera	Staphylinidae	Silphidae	Staphylinidae	
			Histeridae		
			Staphylinidae		
			Chrysomelidae		
	Hemiptera				Reduviidae
	Other	Collembola		Opiliones	Collembola
6	Diptera	Sarcophagidae	Calliphoridae	No collecting	No collecting
			Sepsidae		
			Lonchopteridae		
	Hymenoptera	Formicidae	Braconidae		
	Coleoptera		Staphylinidae		
	Orthoptera		Gryllidae		

Table 1. Continued.

Days postmortem	Order[a]	September 13, 1991		October 1, 1991	
		CO_2	SP	CO_2	SP
	Other	Opiliones	Acar		
7	Diptera	Muscidae Sphaeroceridae	Muscidae	Psychodidae	Sciaridae
	Hymenoptera		Braconidae		
	Coleoptera			Staphylinidae	Staphylinidae
	Orthoptera		Gryllidae		
	Other	Collembola		Collembola	Collembola Opiliones
8	Diptera	Sphaeroceridae	Calliphoridae Muscidae	Calliphoridae Sphaeroceridae	Calliphoridae Sarcophagidae Sphaeroceridae
	Coleoptera			Staphylinidae	Staphylinidae
	Hymenoptera				Braconidae
	Orthoptera		Gryllidae		
	Other	Collembola		Collembola	
				days 9–17	
9	Diptera		Muscidae	Sphaeroceridae	
	Coleoptera			Staphylinidae	Staphylinidae
	Hymenoptera		Formicidae		Braconidae
	Orthoptera		Gryllidae		
10	Diptera	Sarcophagidae	Sarcophagidae Calliphoridae Sepsidae Sphaeroceridae		
	Coleoptera		Staphylinidae		
	Hymenoptera	Formicidae	Formicidae		
	Other	Collembola			
11	Diptera	Muscidae	No arthropods		

Table 1. Continued.

Days postmortem	Order[a]	September 13, 1991		October 1, 1991	
		CO_2	SP	CO_2	SP
	Hymenoptera	Formicidae			
	Other	Collembola			
12	Diptera	Sphaeroceridae	Sphaeroceridae		
	Other	Collembola	Araneae		
		Acari			
13	Diptera		Sphaeroceridae		
to	Hymenoptera		Formicidae		
39	Coleoptera		Staphylinidae		
	Other	Collembola	Collembola		

[a] Taxa listed in order of abundance.

Table 2. Adult arthropods collected from rats euthanized by CO_2 anoxia and sodium pentobarbital (SP) overdose.

Taxa	Adults collected	Percent on CO_2 rats	Percent on SP rats	Percent of total
Diptera	417	27.3	72.7	84.4
Coleoptera	27	51.9	48.2	5.5
Hymenoptera	20	30.0	70.0	4.1
Hemiptera	6	16.7	83.3	1.2
Others	24	25.0	75.0	4.9
Total	494	28.5	71.5	100

were visited by calliphorid (*Lucilia* sp., *Phaenicia* sp. and *Phormia* sp.), sarcophagid (*Sarcophaga* sp.) and muscid (Muscidae) flies; braconid (Braconidae) wasps, collembolans, ants and opilionids. The remaining CO_2 rat was observed for 15 d.

Twelve d postmortem distention waned in the remaining CO_2 rat and calliphorid larvae were seen feeding around the vaginal and anal area. Three d later, this rat was still intact, although a putrid smell was evident. The mean afternoon temperature for Oct. 18–Nov. 1 was 15°C (7–23°C). Average rainfall was 0.03 cm and 6 of the 15 d were overcast. The few arthropods associated with the Oct. 18 rats are not included in Table 1.

Fauna. A total of 494 adult arthropods were collected from the seven rats, 28.5% from the four CO_2 rats and 71.5% from the three SP rats (Table 2). Except for the Coleoptera, the majority of adult arthropods were collected from the SP rats compared to CO_2 rats ($P < 0.05$). Diptera accounted for 84% (417/494) of the adult arthropods collected ($P < 0.05$) and 76% (319/417) were Calliphoridae. The predominant calliphorids were *Phaenicia* sp., *Opsodexia* sp., *Lucilia illustris* (Meigen), *Phormia regina* (Meigen) and *Cochliomyia macellaria* (F.). Muscidae accounted for 5.7% (24/417) and Sarcophagidae accounted for 3.4% (14/417) of the Diptera. The remaining families: Sphaeroceridae, Chloropidae, Sepsidae, Lonchopteridae, Phoridae, Ephydridae, Sciaridae and Piophilidae accounted for 14.4% (60/417) of the Diptera.

Seventy-four percent (20/27) of the adult Coleoptera were staphylinids. The genera *Philonthus* sp., *Aleochara* sp., *Omalium* sp. and the predatory species *Creophilus maxilossus* (L.) were predominant. Other beetles associated with the rat carcasses were histerids, incidental leaf beetles (Chrysomelidae) and the carrion beetles *Silpha* sp. and *Nicrophorus* sp., the latter carrying numerous phoretic *Poecilochirus* sp. mites.

DISCUSSION

Both groups of rats attracted similar arthropods. Diptera accounted for 84% (417/494) of collected adults with Coleoptera, Hymenoptera, Hemiptera and others representing between 1–5.5% each. Other arthropods included acarines (Acari), opilionids (Opiliones), gryllids (Gryllidae), collembolans and spiders (Araneae). The number of taxa were fairly constant for CO_2 rats but diverse at the beginning and poor at the end for SP rats. Seventy-one percent (353/494) of adult arthropods were associated with the SP rats.

CO_2 rats decomposed as expected for small rodents (Lane, 1975). Adult insect activity increased from day 2–3, decreased from 4–5 and stabilized after day 5. The SP rats exhibited heightened adult activity from d 2–5 and did not exhibit significant reduction in insect activity until day 7. Increased fly activity on d 2 for both CO_2 and SP rats followed the initial calliphorid oviposition and was comprised of sarcophagids, sphaerocerids, muscids, chloropids, piophilids, sepsids and ephydrids. The CO_2 rats decomposed in half the time as SP rats and were unavailable for additional waves of opportunistic feeders and facultative necrophages. By comparison, when only the bones, hair and skin of the CO_2 rats remained, the SP rats were bloated with feeding second instars. Even 9 d postmortem first instars were detected in SP rats. Calliphorid oviposition on SP rats appeared protracted throughout the 7 d of putrefaction.

Although we did not test for the presence of SP in decomposing rat tissues or in the carrion feeding insects, our results indicate that SP affects fly oviposition and feeding patterns. The presence of SP in the tissues may have inhibited fly larval feeding and development particularly in the abdominal region where the highest concentrations of SP residues would be expected following an intraperitoneal injection. We found Diptera larval feeding concentrated in the genito-anal area, upper thorax and face of the SP rats while most of the gastrointestinal tract and abdominal mesentery was uneaten. Delayed oviposition and larval feeding and development were observed on mercury contaminated fish tissues (Nuorteva and Nuorteva, 1982) and on malathion contaminated human tissues (Gunatilake and Goff, 1989).

Smith (1976) stressed the need for faunal succession studies on whole animal carcasses because similar studies on intact human corpses under field conditions were not ethically or morally possible. Methods used to euthanize animals in experimental studies affect faunal succession as does the kind and size of the animal used (Denno and Cothran, 1975; Hewadikaram and Goff, 1991). For instance, carbon monoxide gas changes the blood hemoglobin which alters body tissues and affects the rate of decomposition and carcasses with artificial wounds would desiccate more rapidly and affect results (Smith, 1976). We compared rats of similar weight euthanized by CO_2 anoxia and SP overdose which also kills by anoxia. Death by cervical fracture occurs through the elimination of the brain blood supply and central nervous system input and is not equivalent to SP euthanasia. Furthermore, cervical fracture is not suitable for animals >100 gm (Muir III and Hubbell, 1995). Although a rise in blood pH would be expected from both CO_2 and SP euthanasia, the latter due to glycolysis after death, CO_2 leaves no residues while SP, which is highly lipid soluble, is concentrated in the fatty tissues. In fact, Beyer et al. (1980) detected phenobarbital, a related barbiturate, in *C. macellaria* larvae feeding on the decomposed remains of a fatal overdose case.

Care must be taken in estimating PMIs from insects feeding on corpses containing poison, drug and toxin residues. Jirón and Cartín (1981) observed insect succession on a dog euthanized with SP during the dry season in Costa Rica. The ecological complexity and fauna associated with the dog's decomposition were reportedly due to the premontane humid climate. Unfortunately, the authors did not consider manner of death in their study of insect succession. Utsumi et al. (1958) identified insects attracted to rats euthanized nine different ways. Insect succession to poisoned rats was fairly constant however, rats euthanized mechanically exhibited plentiful insect

activity at first that later declined. We observed prolonged adult activity and larger numbers of adults on SP rats most likely because SP rats took twice as long to decompose as CO_2 rats.

Although manner of death influences insect succession and development of sarcophagous insects (Smith, 1976). Rats euthanized and placed outside on Sept. 13 decomposed twice as fast as rats euthanized and placed outside on Oct. 1. The mean temperature from Sept. 13–24 was 24°C whereas the mean temperature from Oct. 1–17 was 18°C. Higher temperatures in September accelerated fly larval development and enhanced bacterial putrefaction. Adult Diptera were more numerous in September than October. Two d postmortem a 1 cm larva was found within the perineoscrotal cavity of the Sept. 13 SP carcass. This anomaly may be explained by localized larval mass heat generation or by early hatching. The predominance of calliphorid, sarcophagid, muscid, piophilid, sepsid and phorid larvae in the September rat carcasses increased the rate of decomposition. Although interesting, many of these syanthropic flies are not encountered in typical forensic investigations (Catts and Haskell, 1990). Facultative necrophages, such as Collembola, ants, opilionids, crickets and yellowjackets also were more abundant in September than in October.

Conspicuously missing are the Coleoptera families Trogidae, Dermestidae, Cleridae, and Nitidulidae that are frequently collected from advanced decay and dry stages of carrion (Payne and King, 1970; Smith, 1986). Nocturnal beetles may have been missed because we collected during the day. Other beetles may have been inhibited by the truncated photoperiod of September and October, sporadic rain, the small size of the rat carcasses or an unsuitable biochemical microclimate, all factors to consider in forensic entomology studies.

LITERATURE CITED

Beyer, J. C., W. F. Enos and M. Stajic. 1980. Drug identification through analyses of maggots. J. Forensic Sci. 25:411–412.

Catts, E. P. 1992. Problems in estimating the postmortem interval in death investigations. J. Agric. Ent. 9:245–255.

Catts, E. P. and N. H. Haskell. 1990. Entomology & Death: A Procedural Guide. Joyce's Print Shop, Inc., Clemson, SC, 182 pp.

Denno, R. and W. R. Cothram. 1975. Niche relationships of a guild of necrophagous flies. Ann. Ent. Soc. 68:741–745.

Glaister, J. and E. Rentoul. 1966. Medical Jurisprudence and Toxicology. E&S Livingstone Ltd., London, 724 pp.

Goff, M. L. and W. D. Lord. 1994. Entomotoxicology: a new area for forensic investigation. Am. J. Forensic Med. Pathol. 15:51–57.

Goff, M. L., A. I. Omori and J. R. Goodbrod. 1989. Effect of cocaine in tissues on the development rate of *Boettcherisca peregrina* (Diptera: Sarcophagidae). J. Med. Ent. 26: 91–93.

Goff, M. L., W. A. Brown, K. A. Hewadikaram and A. I. Omori. 1991. Effect of heroin in decomposing tissues on the development rate of *Boettcherisca peregrina* (Diptera: Sarcophagidae) and implications of this effect on estimation of postmortem intervals using arthropod development patterns. J. Forensic Sci. 36:537–542.

Goff, M. L., W. A. Brown and A. I. Omori. 1992. Preliminary observations of the effect of metamphetamine in decomposing tissues on the development rate of *Parasarcophaga*

ruficornis (Diptera: Sarcophagidae) and implications of this effect on the estimations of the postmortem intervals. J. Forensic Sci. 37:867–872.

Goff, M. L., W. A. Brown, A. I. Omori and D. A. LaPointe. 1993. Preliminary observations on the effects of amitriptyline in decomposing tissues on the development of *Parasarcophaga ruficornis* (Diptera: Sarcophagidae) and implications of this effect to estimation of postmortem interval. J. Forensic Sci. 38:316–322.

Gunatilake, K. and M. L. Goff. 1989. Detection of organophosphate poisoning in a putrefying body by analyzing arthropod larvae. J. Forensic Sci. 34:714–716.

Hewadikaram, A. A. and M. L. Goff. 1991. Effect of carcass size on rate of decomposition and arthropod succession patterns. Am. J. Forensic Med. Pathol. 12:235–240.

Jirón, L. F. and V. M. Cartín. 1981. Insect succession in the decomposition of a mammal in Costa Rica. J. New York Ent. Soc. 89:153–165.

Keh, B. 1985. Scope and applications of forensic entomology. Ann. Rev. Ent. 30:137–154.

Lane, R. P. 1975. An investigation into blowfly (Diptera: Calliphoridae) succession on corpses. J. Nat. Hist. 9:581–588.

LeClerq, M. and F. Vaillant. 1992. Entomologie et medecine legale: une observation inedite. Ann. Soc. Ent. Fr. 28:3–8.

Lord, W. D. 1990. Case studies of the uses of insects in investigations. *In:* E. P. Catts, and N. H. Haskell (eds.), Entomology and Death: A Procedural Guide. Joyce's Print Shop, Inc., Clemson, SC, 182 pp.

Lord, W. D. and J. F. Burger. 1983. Collection and preservation of forensically important entomological materials. J. Forensic Sci. 28:936–944.

Mann, R. W., W. M. Bass and L. Meadows. 1990. Time since death and decomposition of the human body: variables and observations in case and experimental field studies. J. Forensic Sci. 35:103–111.

Muir III, W. W. and J. A. E. Hubbell. 1995. Handbook of Veterinary Anesthesia. Mosby-Year Book, Inc., St. Louis, MO, 510 pp.

Nuorteva, P. and S. L. Nuorteva. 1982. The fate of mercury in sarcosaprophagous flies and in insects eating them. Ambio. 11:34–37.

Payne, J. A. and E. W. King. 1970. Coleoptera associated with pig carrion. Ent. Month. Mag. 105:224–232.

Smith, K. G. V. 1986. A Manual of Forensic Entomology. Cornell University Press, Ithaca, NY, 205 pp.

SYSTAT for the Macintosh. 1992. Version 5.2, Systat, Inc., Evanston, IL.

Utsumi, K., M. Makajima, T. Mitsuya and K. Kaneto. 1958. Studies on the insects congregated to the albino rats died of different causes. Ochanomizu Med. J. 7:119–129.

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